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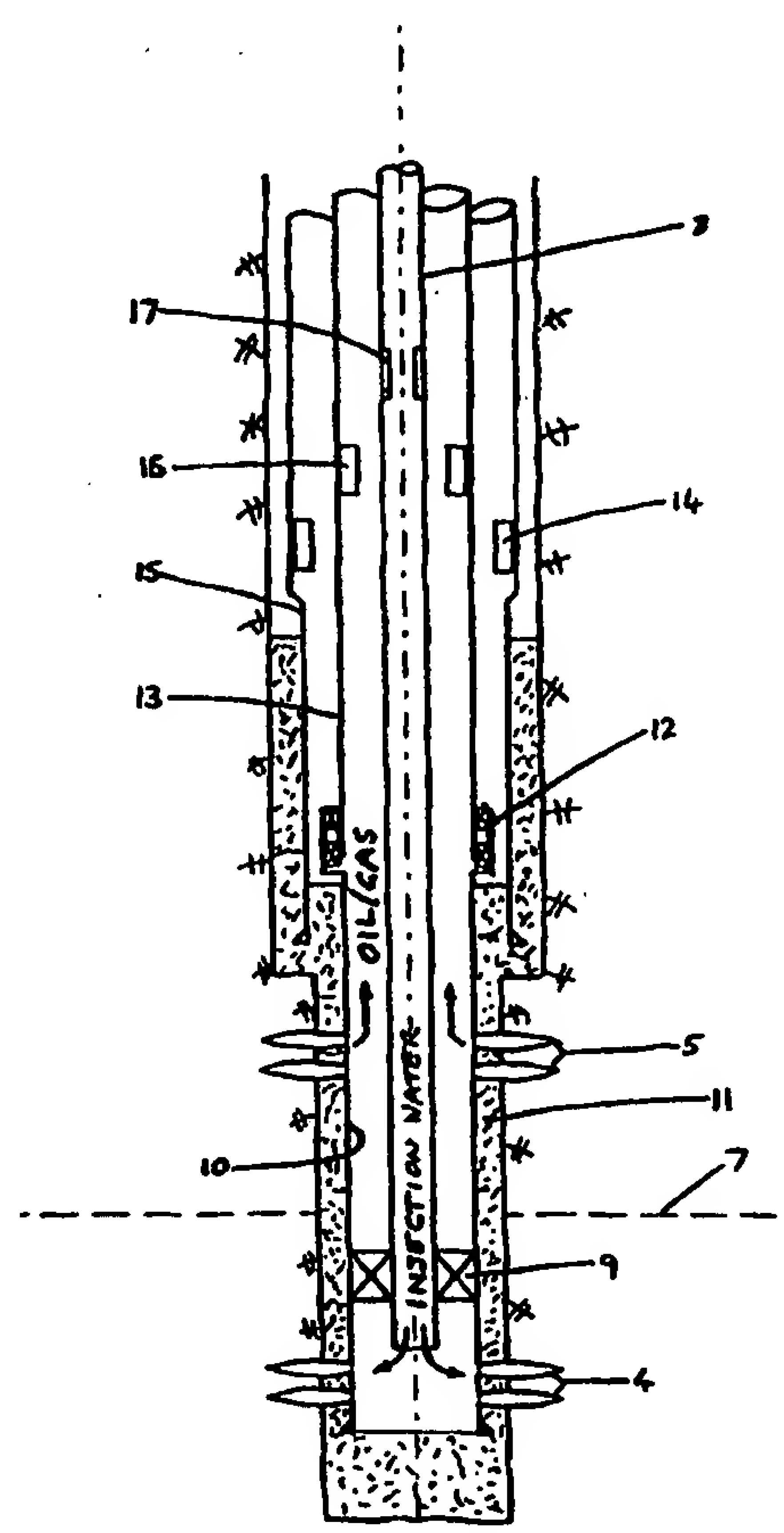
(54) Title: SIMULTANEOUS PRODUCTION AND WATER INJECTION WELL SYSTEM

(57) Abstract

A method and apparatus are provided for enabling the simultaneous injection of treated water into an aquifer and production of the petroleum from the reservoir immediately above. A Xmas tree is provided to support two tubular strings running from set positions in the well to allow conveyance of fluids as the well conditions and operations require. The inner tubing string (8), runs from the Xmas tree to a cemented casing string, known as a "liner" (10), which is entirely set downhole. The tubing is for conveying injection water down from surface and into the aquifer, or hydrocarbons out of another or same reservoir to surface. The outer tieback tubing string (13), is provided to run from the Xmas tree to a sealing receptacle (12) at the top of the liner. The liner is additionally perforated (5) below the sealing receptacle at selected positions in the hydrocarbon reservoir above the lower packer position. This outer string conveys petroleum from the reservoir to surface and through the Xmas tree to process plant.



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SIMULTANEOUS PRODUCTION AND WATER INJECTION WELL SYSTEM

1. Field of the Invention

The present invention relates to the simultaneous injection of water into an aquifer beneath an oil reservoir and the production of fluids therefrom through one single drilled borehole completed with casing and tubing.

2. Description of the Prior Art

Economic circumstances and trends have obliged companies and technologists involved in the exploration for and production of petroleum to seek sound methods of cost reduction. One such major cost is that incurred in the very drilling of the wells themselves through which petroleum is produced, or water injected to maintain the reservoir pressure that drives petroleum towards the surface. Prior art methods for reservoir exploitation require drilling of a number of wells of which there are two kinds; production wells, through which hydrocarbons are conveyed to surface for subsequent processing, marketing, and sale; and injection wells though which suitably treated water is forced under pressure into the aquifer supporting the oil reservoir thereby maintaining the reservoir pressure as petroleum is being removed. Production wells are often subsequently converted to injection wells as reservoir conditions change in the course of exploitation.

The importance of maintaining reservoir pressure is that it maximises the yield of hydrocarbons.. Should this pressure be allowed to fall through short-sighted overproduction, flow rates to surface shall be reduced and gas shall evolve from the liquids. These gases are more mobile than the heavier and more valuable medium hydrocarbons and shall be produced preferentially to the liquids which may be left in the reservoir.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of this invention are set against the background of its applications in the detailed description which follows and in conjunction with accompanying drawings wherein:

Figure 1 depicts a sectional elevation of a well drilled through an oil-bearing reservoir into the aquifer immediately beneath.

Figure 2 depicts a producer-injector downhole completion highlighting all principal technical and geological features.

Figure 3 depicts the Xmas tree and associated equipment which enables simultaneous production and injection operations.

Figure 4 depicts the configuration of equipment for drilling operations through the Xmas tree.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 is a sectional elevation of a well 1 drilled through an oil-bearing reservoir 2 into the aquifer 3 immediately beneath. The well has been shown as deviated as such producer-injector wells shall typically seek to maximise the distance between the injection perforations and production perforations to prevent or minimise the effect known as "coning", a phenomenon where water is attracted to production perforations thereby permaturely increasing the water cut of produced fluids. The deviation, profile, and perforation positions shall be established by reservoir experts using geological and petrophysical data.

Injection perforations 4 allow ingress under applied pressure of injection water into the aquifer beneath the petroleum reservoir. Production perforations 5 in the oil-bearing formation permit inward flow of petroleum into the active annulus and up to the Xmas tree. For brevity, the illustration depicts an offshore platform 6 as the origin of the well. The oil-water contact 7 is the interface between the hydrocarbon reservoir and the aquifer.

Figure 2 is a depiction of a producer-injector completion. Injection tubing string 8 extends from the Xmas tree (not shown) through packer 9 into the area of the well in the proximity of the injection perforations 4. The packer ensures that injected and produced fluids are isolated from each other. Further up the well are production perforations 5 through which hydrocarbons enter the active annulus. The positions of both injection and production perforations shall be dependant upon factors pertaining to each individual well particularly; location of oil-water contact 7, angle of deviation of well, location of faults and fractures, permeability of formation. A downhole liner string 10 extends from the bottom of the well to a position typically 100-200 metres measured length above the shoe of the surface casing. The liner string, which is fully encased in cement 11, has a sealing receptacle 12

located at, and attached to, its upper end. Into this receptacle is run a tieback tubing string 13, the downhole extremity of which seals in the receptacle. The sealing receptacle may accommodate movement of tieback tubing due to thermal and pressure effects whilst maintaining a fully functioning seal. An annular safety valve 14 installed, if required, in the surface casing 15 at a position above the level of cement provides protection for the passive annulus in which pressure may change should the tieback tubing-downhole liner combination develop a leak. Annular safety valve 16 ensures that hydrocarbon production ceases in the event of an emergency because it closes the active annulus. Sub-surface safety valve 17 installed, if required, in the tubing string also closes in the event of an emergency and prevents injection of water into the aquifer or, alternatively, halts production of hydrocarbons from a hydrocarbon reservoir.

Figure 3 depicts the Xmas tree arrangement for a completed well. The Xmas tree block 18 has two profiles, lower and upper, into which are landed production tieback tubing hanger 19 and injection tubing hanger 20 respectively. The hangers have their associated seals 21 and 22 to ensure isolation of conveyed fluids. In the injection tubing hanger is installed a plug 23 which is removed in the event of workover. Crown plugs 24 are installed in dedicated profiles in the upper end of the tree block. Both the upper and lower external ends of the tree block have profiles machined to enable mechanical connection to a blowout preventer (BOP) 25 and the wellhead 26 respectively. Valves are essential elements of the system. Mechanically attached to, or integral to, the tree block are valve blocks 27 and 28 allowing and controlling flow of production fluids up, or injection fluids down, the tubing bore, and production fluids up the active annulus.

Figure 4 depicts the situation after the production tieback-casing hanger is set in the Xmas tree lower bowl. A bowl protector 29 , which is removed after completion of all drilling, protects the sealing surfaces for the subsequently

installed hangers. Prior art methods have installed the wellhead and surface casing strings.

An example of a casing program to which this invention is applicable would be a surface string of 10-3/4 in. x 9-5/8 in. (273mm x244.5mm)to 13,000 feet (c. 4000 metres) measured depth, a downhole liner of 7 in. (177.8mm) from 12700ft to 17,000ft measured depth (c. 3900 metres to 5000 metres) and a tieback string of 7-5/8 in.(193.7mm). The injection tubing of 5 in. diameter (127mm) would run to 16,500ft measured depth (c. 4800 metres). It is probable that the well would be highly deviated and the liner program could be adjusted to 7-5/8 in. x 5 in.(193.7mm x 127mm) with the packer being set immediately above the crossover. The 5 in. section would be the conduit for injection fluid from the 5 in.(127mm) tubing, the well now being of the monobore type for operational advantage. The perforation program for a highly deviated well may require the injection perforations to be undertaken by coiled tubing.

This present invention provides several advantages over the prior art. It is current practice that dedicated injection wells be drilled to support a hydrocarbon reservoir where a suitable aquifer is present. There are several examples where short-sighted and precipitous production of reservoirs has reduced the reservoir pressure below viability with subsequent costly measures taken to re-pressurise through water injection. This invention, if employed at the outset of a development program, ensures maintenance of reservoir pressure at no additional drilling costs. This invention is applicable to those reservoirs where water injection is feasible and desirable on the basis of geological and petrophysical factors. For example, where a field development program envisaged twelve production wells and eight injection wells would, using the PI-system, only require twelve wells. The cost savings in the drilling program are in the order of 40% for such a field.

The Xmas tree enables implementation of PI-wells, and is indispensable to the minimisation of capital and operating costs.

Although the invention has been described with reference to a specific embodiment, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiment as well as alternative embodiments of the invention will become apparent to persons skilled in the art upon reference to the description of the invention. Examples of such modifications include, inter alia: removing the upper shoulder in the Xmas tree and landing the tubing hanger on the tieback tubing hanger; splitting the tree block into two separate spools for hanging equipment. It is therefore contemplated that the appended claims will cover any such modifications or embodiments that fall within the scope of the invention. It is further contemplated; i) that injection fluids may be injected directly into the hydrocarbon reservoir instead of the supporting aquifer substantially where the permeability of the aquifer formation is very low relative to that of the reservoir formation, ii) that gas lift operations may be effected by including suitable mandrels in the tieback tubing string allowing gas to enter the active annulus from the hitherto passive annulus, and iii) that suitable sub-surface pumps using the injection fluid as the drive fluid passing through to the aquifer, could be employed to enhance the production of hydrocarbons.

CLAIMS

I claim;

1. A Xmas tree for setting on, and mechanical attachment to, a wellhead for installed casing strings of a completed well when used in the simultaneous but separate production of hydrocarbons from selected sectors of a reservoir, or of a contiguous reservoir, in a single drilled well, or in the simultaneous production of hydrocarbons from said reservoir and water injection into an aquifer thereunder in a single drilled well, characterised by each of the produced hydrocarbon streams or both the produced hydrocarbons and injected water flowing through the Xmas tree, said Xmas tree being of surface or subsea types and having internal profiles for reception of hanging and sealing equipment for tubing strings and flow control porting for resultant annuli and bore.
2. The Xmas tree according to claim 1 wherein a profile is disposed internally in the lower section of the Xmas tree body onto which profile is landed, secured, and sealed a hanger for an outer tubing string.
3. The Xmas tree according to claim 1 wherein a further profile is disposed internally in the central section of the Xmas tree body onto which profile is landed, secured, and sealed a hanger for an inner tubing string.
4. The Xmas tree according to claim 1 wherein a further profile is disposed internally in the upper section of the Xmas tree body onto which profile is landed, secured, and sealed one or more plugs or capping mechanisms.
5. The Xmas tree according to claim 3 wherein the inner tubing hanger is landed upon the previously installed outer tubing hanger.
6. The Xmas tree according to claim 2 wherein the outer tubing hanger hangs off a tubing string which is tied into a tieback receptacle sited at the upper extremity of a pre-installed liner.
7. The Xmas tree according to claim 1 wherein two separate valve systems are attached to, or integral to, the Xmas tree body.

8. The Xmas tree according to claim 7 wherein the upper valve block provides fluids with access to, or egress from, the void between the aforementioned plug(s) and the aforementioned inner tubing hanger and attached tubing string extending downhole.
9. The Xmas tree according to claim 7 wherein the lower valve block provides fluids with access to, or egress from, the void between the aforementioned inner tubing hanger and outer tubing hanger, and the annulus formed by the tubing strings attached respectively thereto.
10. The Xmas tree according to claim 1 in which the flow control port to the annulus, as formed by the outer tubing string as inner surface and the casing string precedent thereto as outer surface, is adapted for gas-lift operations.
11. The Xmas tree according to claim 1 in which the Xmas tree block is split into separate spools for hanging and sealing equipment.
12. A method for simultaneous but separate production of hydrocarbons from sectors of a reservoir in a single drilled well; and for simultaneous or singular water injection into underlying aquifer and hydrocarbon production from said reservoir, also in a single drilled well, possibly the same well as the former after conversion of the lower sector from hydrocarbon production to water injection; comprising the following steps beyond the prior art of:
    a) drilling a targetted deviated primary well bore through a hydrocarbon reservoir.
    b) obtaining the desired angle of deviation from the vertical, and continuing to drill primary well bore to sectors of reservoir offset from the first sector destined for production.
    c) drilling further through the reservoir into the underlying aquifer.
    d) running a liner in the wellbore and cementing in situ.
    e) running and installing a tubing string which ties into a tieback receptacle sited at the upper extremity of the liner; the tubing being hung from its hanger installed in the lower profile of the Xmas tree.
    f) perforating the liner at intervals as required by development program etc. said perforations being set at intervals in the reservoir.

g) running and installing a second tubing string and setting the packer below the existing perforations, this second tubing string being hung from the tubing hanger installed in the central profile of the Xmas tree.

h) further perforating in the liner section below the packer, these perforations being preferably sited in the underlying aquifer or just above the oil-water contact.

13. The method according to claim 12 wherein hydrocarbons are produced up the annulus formed by the inner and outer tubing strings with produced fluids flowing through the lower valve system.

14. The method according to claim 12 wherein hydrocarbons are produced up the tubing string with produced fluids flowing through the upper valve system.

15. The method according to claim 12 wherein injection fluids are pumped down the inner tubing string and injected into the aquifer.

16. The method according to claim 12 comprising simultaneously the methods of claim 13 and claim 14.

17. The method according to claim 12 comprising simultaneously the methods of claim 13 and claim 15.

18. The method according to claim 12 wherein the chronological order of events e) to h) is subject to variation.

19. The method according to claims 13, 16, and 17 wherein the annular production of hydrocarbons is assisted by gas-lift, said gas entering the production annulus from the passive annulus through gas-lift mandrels suitably sited in the tieback tubing string.

20. The method according to claims 13, 16, and 17 wherein the annular production of hydrocarbons is assisted by a downhole pump using injection fluid pumped down the tubing as the drive fluid for the annular rotor which provides additional lift to the hydrocarbons in the annulus, said injection fluid exhausting through the pump en route to the injection perforations.

Figure 1 - Well Schematic

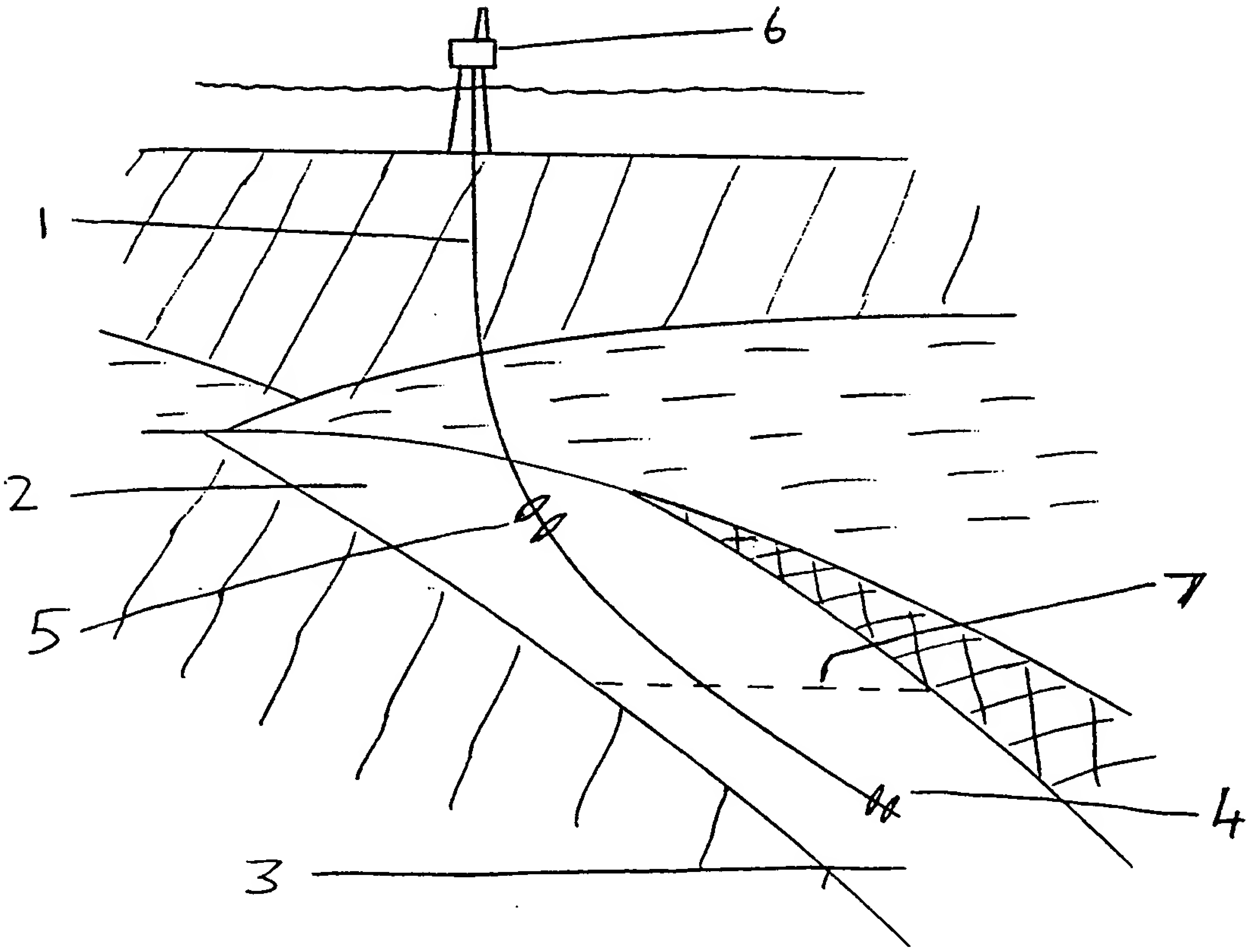


Figure 2 - Producer-Injector Downhole Completion

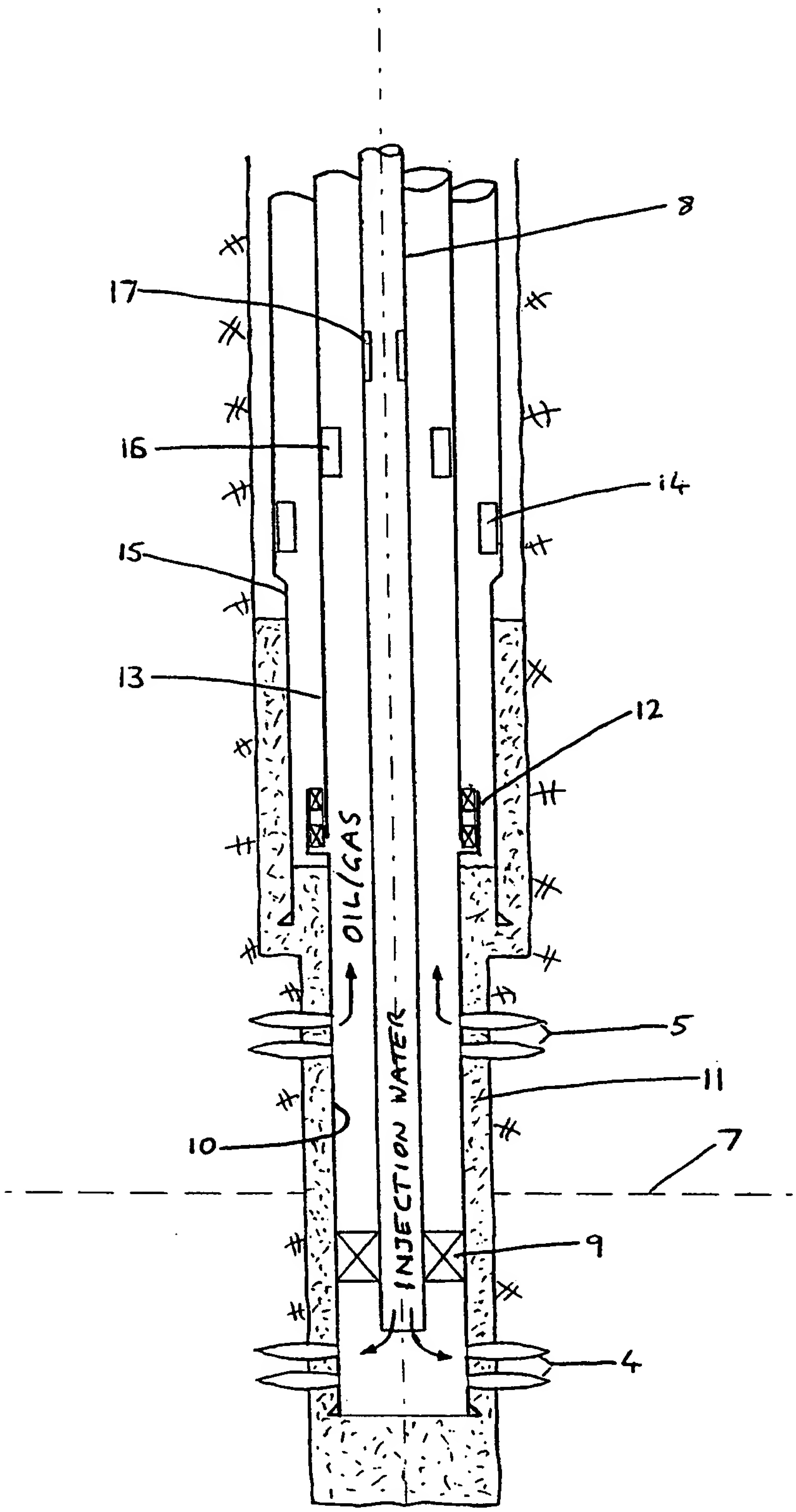


Figure 3 - Producer-Injector Xmas Tree

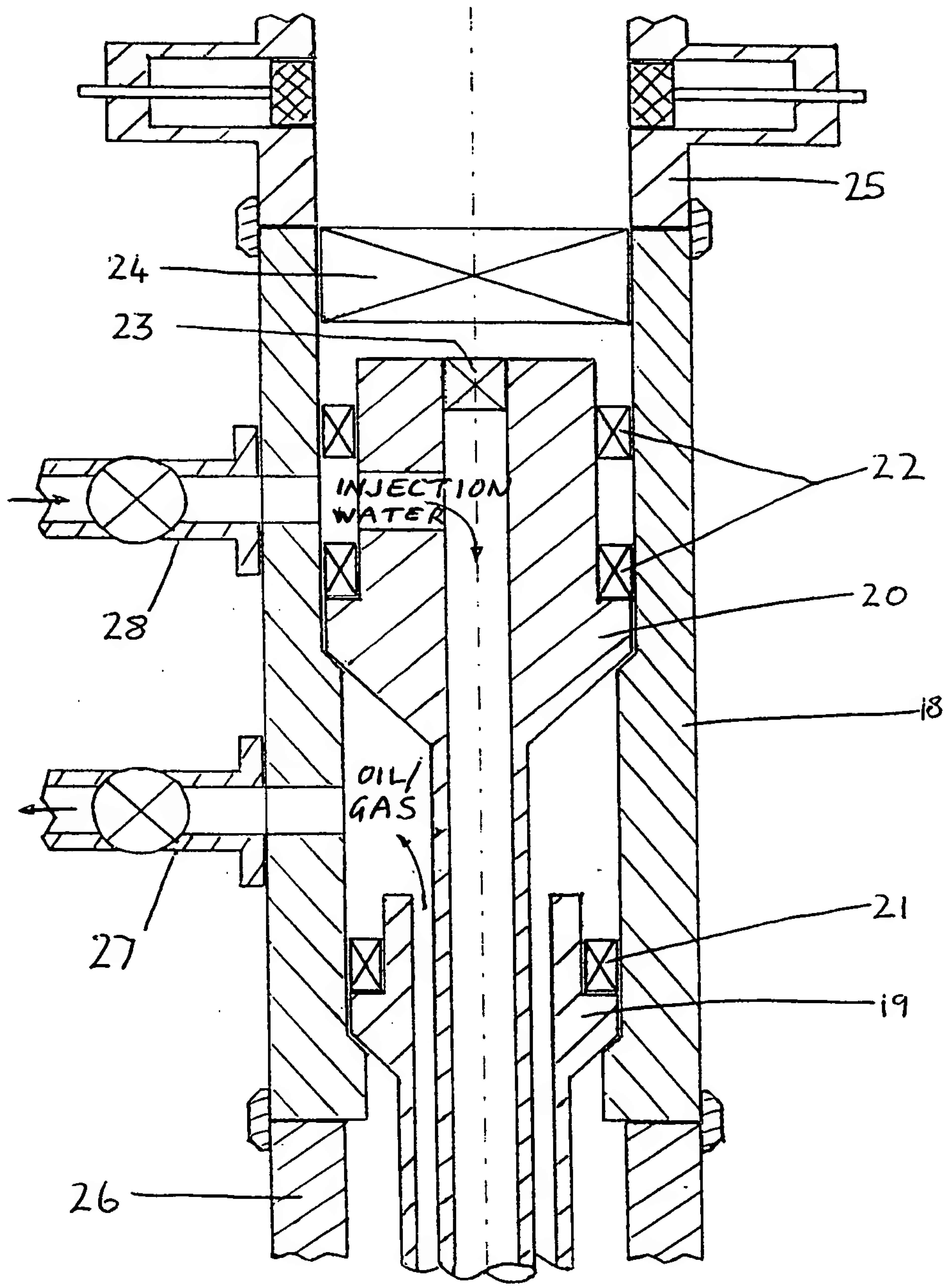
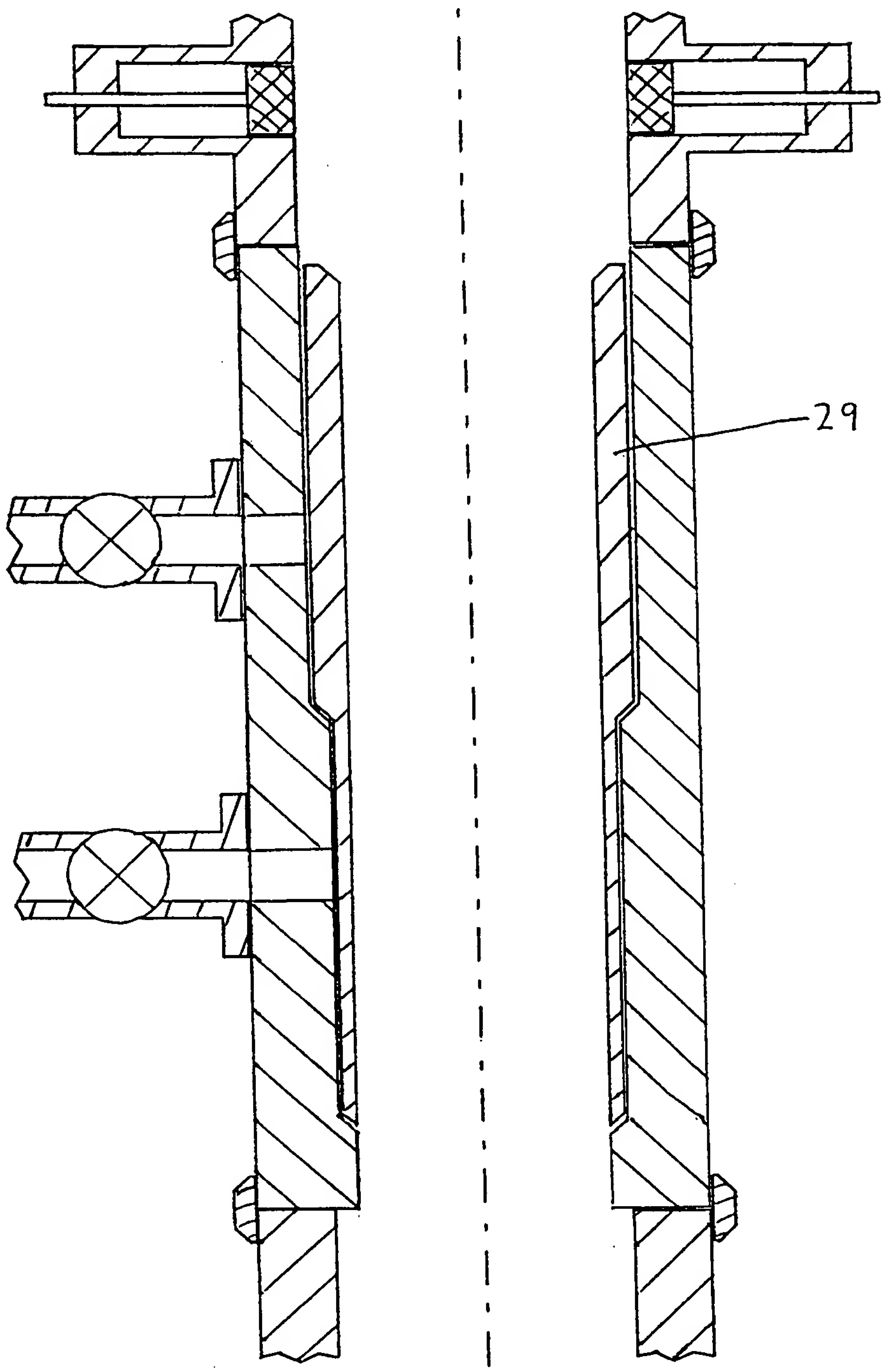


Figure 4 - Drilling Operations



A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 E21B33/047 E21B43/20 E21B43/12 E21B43/14 E21B33/072
E21B43/18

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 254 634 A (BP EXPLORATION OPERATING COMP. LTD) 14 October 1992 see page 5, line 35 - page 6, line 6 see page 13, line 4 - line 35 see page 14, line 19 - line 25 see page 15, line 1 - line 6; figures 10,12,14	1-3,5, 7-10
Y		11
A		12

X	US 2 335 355 A (PENICK ET AL.) 30 November 1943 see page 2, left-hand column, line 17 - line 41 see page 2, right-hand column, line 1 - line 15	1-5,7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
17 March 1998	24/03/1998

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

In ational Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 640 341 A (BRADDICK ET AL.) 8 February 1972 see column 2, line 1 - line 9 see column 2, line 22 - line 33 see column 4, line 36 - line 51 ---	1,6
X	US 3 871 456 A (SIZER ET AL.) 18 March 1975 see column 6, line 57 - column 7, line 38 ---	1
Y	WO 92 08915 A (BARIOD TECHNOLOGY INC.) 29 May 1992 see figure 1 ---	11
E	GB 2 311 312 A (SHARP) 24 September 1997 see the whole document -----	1-20

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Information on patent family members

International Application No
PCT/GB 97/01900

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2254634 A	14-10-92	NONE	
US 2335355 A	30-11-43	NONE	
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GB 2311312 A	24-09-97	NONE	

Form PCT/ISA/210 (patent family annex) (July 1992)

Figure 1 - Well Schematic

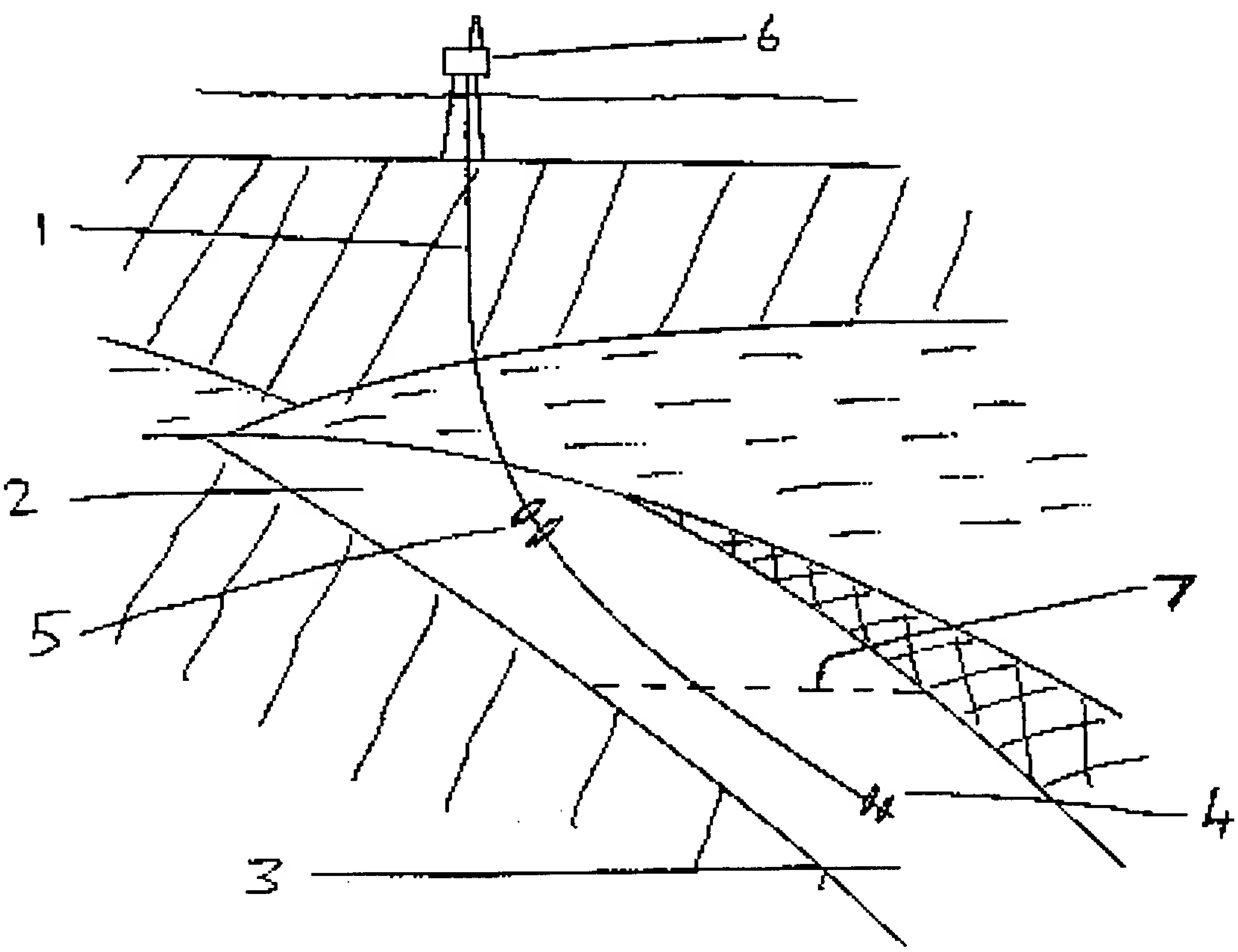

Figure 2 - Producer-Injector Downhole Completion

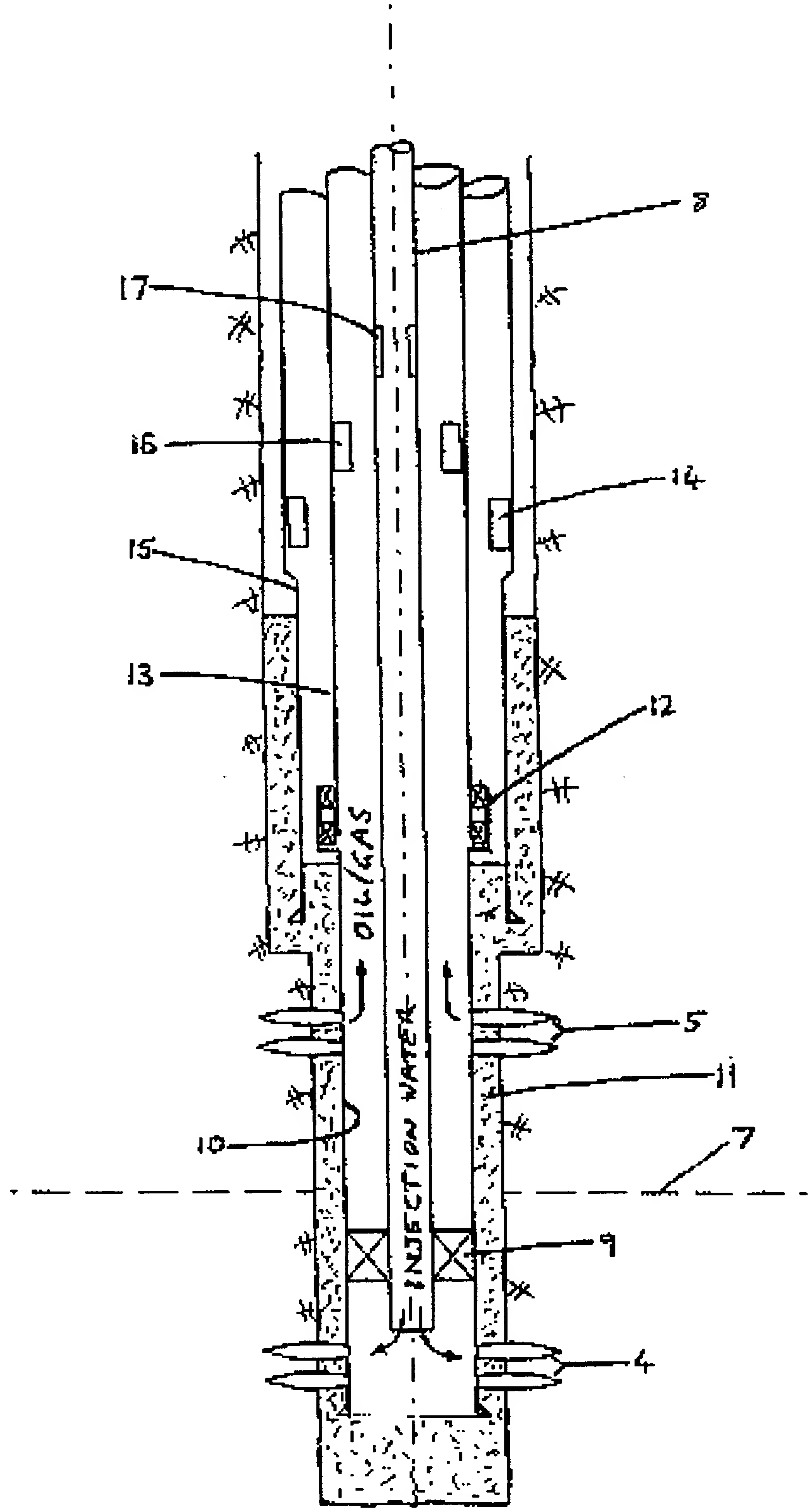

Figure 3 - Producer-Injector Xmas Tree

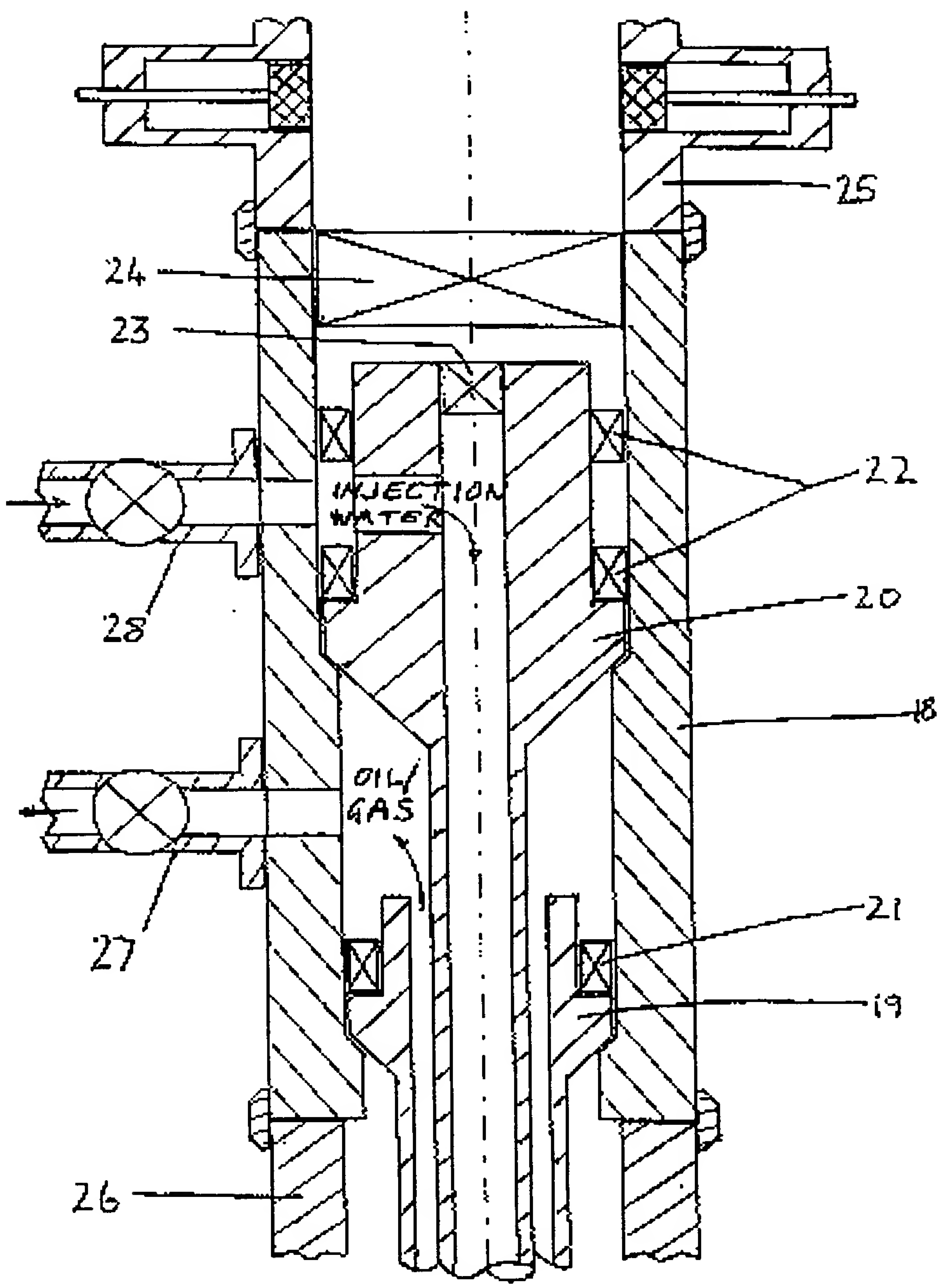

Figure 4 - Drilling Operations